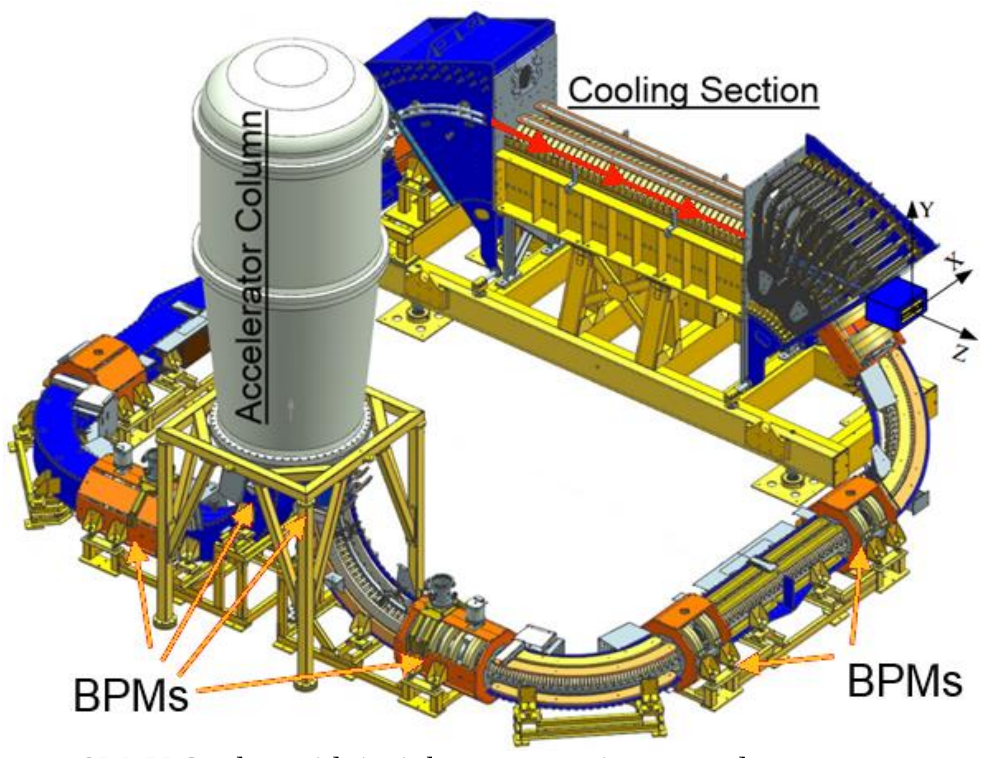
Model Development for the Automated Adjustment of the 2 MeV Electron Cooler Beam Line at COSY

A. Halama, IKP-4

Abstract

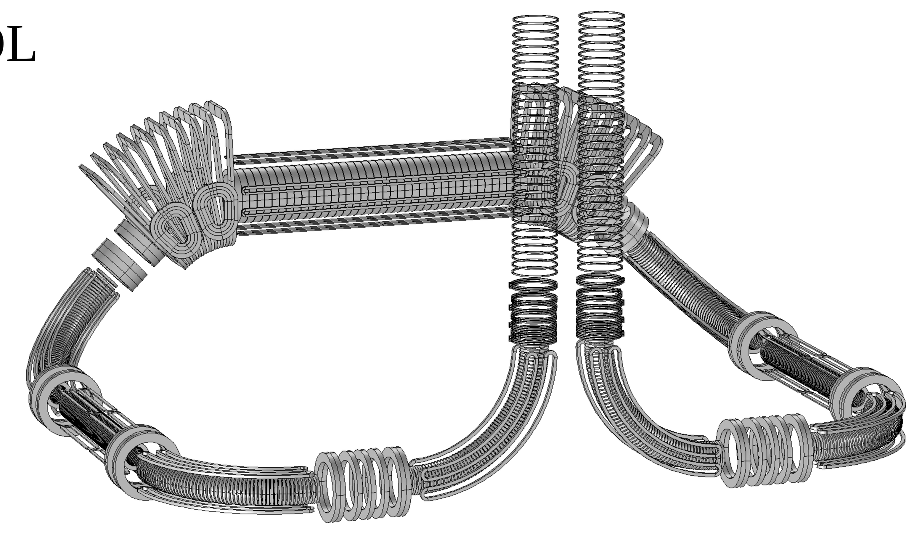
The 2 MeV electron cooler has been installed in the COSY ring to provide e-cooling of p^+ and d^+ beams in the entire energy range of the machine and to study the cooling process in the magnetized regime at high energy. Within the cooling section a velocity-matched electron beam is placed coaxially over the beam circulating in the ring. Coulomb interaction between the beams allows heat transfer analogue to heat exchange of gases. The electron beam is guided by a strong longitudinal magnetic field to preserve its quality. The geometry of the beam line however gives rise to higher order dynamics such as larmor rotation and the so called galloping motion, which must be minimized to yield a cold e-beam. Setting up the cooler and delivering a high quality e-beam by adjusting all required parameters manually is a time consuming task and requires a high level of expertise. The presented model under development shall ease and speed up the adjustment and offer more opportunities for beam control to achieve best possible e-cooling performance.



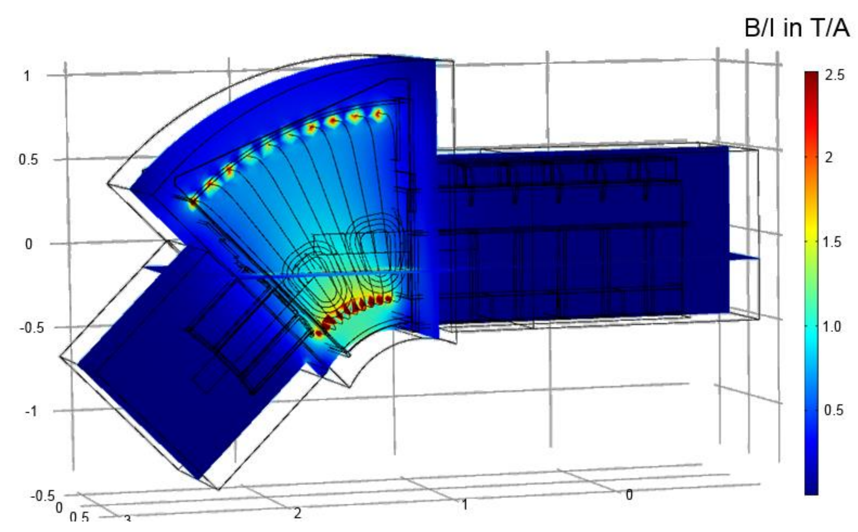
2MeV Cooler, with insight to magnetic system layout

Field Map Calculation

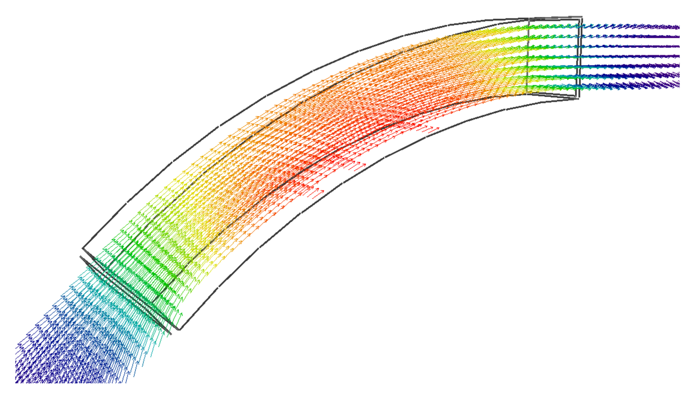
- Simulations carried out in COMSOL
- Modelling of all magnetic components
- Within and without magnetic shielding
- Translation into equidistant maps for easy access
- Initially linear scaling of fields according to set current in model



Assembly of most magnets of the cooler. Seen in COMSOL model view



Multi slice representation of solved magnetic field simulation



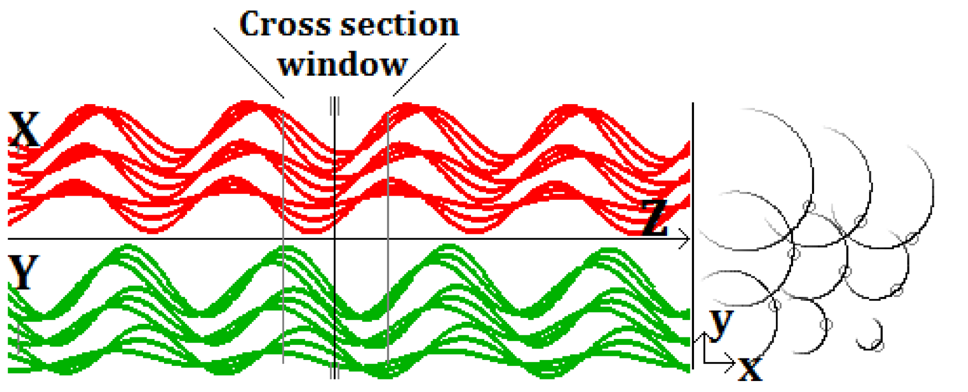
Translated field as equidistant grid for easy access using indexing and interpolation of unit cell

Trajectory Calculation

- Using integration according to equation of motion in E and B fields
- Small larmor radii force small integration steps in ps range
- Computation time ranges from ~ 0.1 s to > 15 s, dep. on setting
- Single trace fit sectionwise with the following form:

$$x(z) = x_0 + mz + A\sin(\omega_m z) + B\cos(\omega_m z)$$

x_0 := initial offset
m := drift ratio
A,B := coefficient of oscillation
ω_m := magnetic wave number
(equivalent for y)



Part of trajectory carrying larmor and galloping in superposition

- Misalignments of longitudinal fields lead to larmor rotation
- Inevitable gradient fields cause additional galloping

References

[1] Alinovskiy, N. et al., "2MeV Electron Cooler for COSY and HESR - First Results", IPAC2014

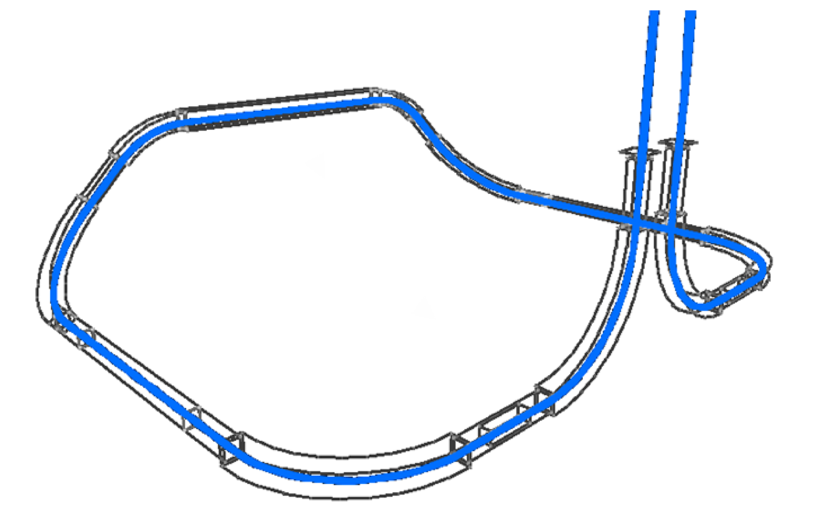
[2] M. Bryzgunov et al., "Magnetic System of Electron Cooler for COSY," BINP SB RAS, Novosibirsk, Russia

[3] A. Halama, "Development of an automatic adjustment of the transport channel of the 2 MeV electron cooler at COSY," Forschungszentrum Jülich, Germany, annual report 2016

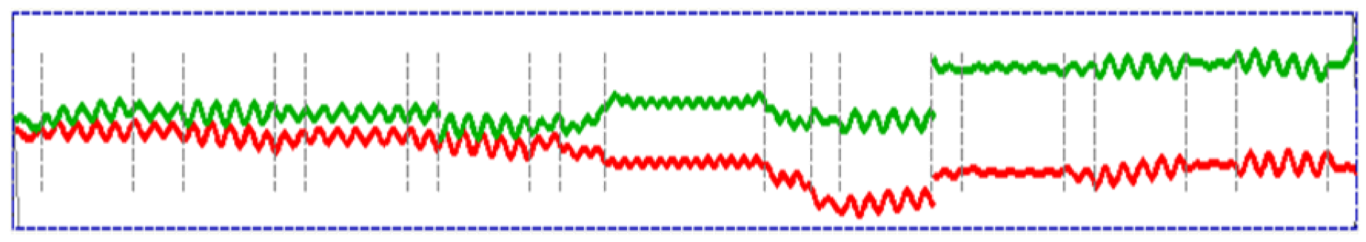
User Interface

Trajectory representation:

- 2D & 3D
- Allows qualitative understanding of the trajectory and
- direct qualitative comparison of multiple traces
- Distribution of electron traces allows understanding of envelope behavior



3D engine allowed easy benchmarking of fields and offers comfortable intuitive way to investigate beam behavior

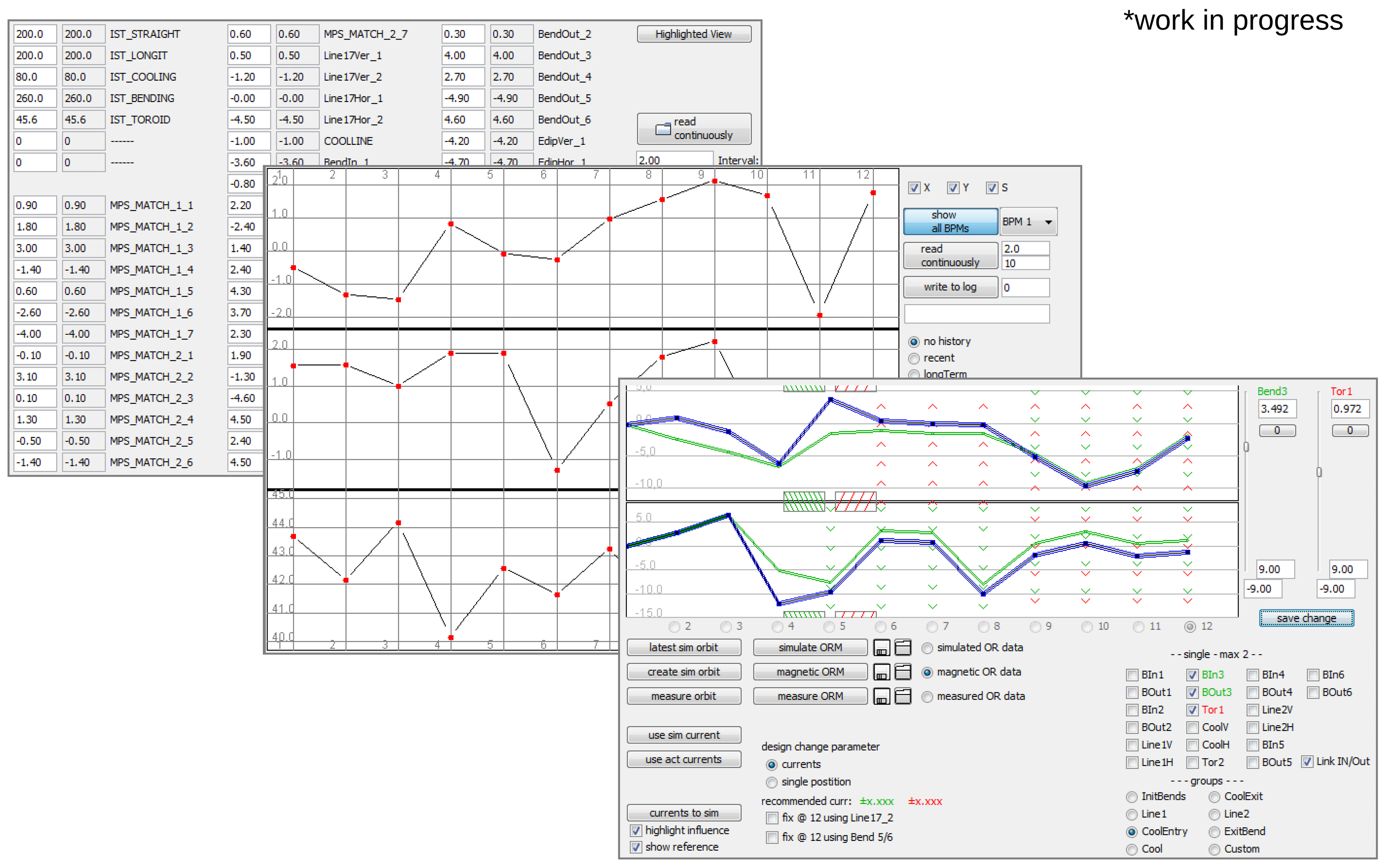


Trajectory is projected onto BPM coordinate plane along the propagation axis

Software features:

- Beam and beam line property monitors
- Manual adjustments and
- testing validity of inputs*
- Logging and archiving*
- Embedded sequenced automated measurements*
- Sequenced operation*
  - synchronization to COSY,
  - boot, - shutdown)

*work in progress



Some images of the GUI (Corrector magnet control, orbit monitor and orbit design tool)

Status and Plans

- Fields of all magnets have been simulated, translated and properly scaled in the model to agree with the cooler magnets field strength per amp
- Preparations are made for later reflection of saturation and hysteresis approximation
- Larmor and galloping compensation work well within the model
  - Trajectory fit coefficient dependency with respect to larmor kicker is measured and applied for compensation
  - Galloping is reduced following the negative gradient response of single matching section coils (7 in total)

Achieved: Relative Matching

- Orbit response matrix can quickly be calculated and applied

Successful use of calculated ORM input in
  - Slow beam feedback system
  - Orbit design tool
- Qualitative agreement of larmor phase propagation through multiple bending sections has been observed compared to the cooler

Next Step: Absolute Matching

- Finding new ways to measure certain characteristic parameters to match model to cooler
  - Measurements and analysis of results are ongoing
- Tracing electrons forth and back from measured (BPM) positions and find least RMS deviation
  - Using larmor parameters to approximate transverse momentum